

PCT

**WORLD INTELLECTUAL PROPERTY ORGANIZATION**  
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : A61F 2/66, 2/74		A1	(11) International Publication Number: WO 00/23017 (43) International Publication Date: 27 April 2000 (27.04.00)		
(21) International Application Number: PCT/US99/23971		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).			
(22) International Filing Date: 21 October 1999 (21.10.99)					
(30) Priority Data: 60/105,532 22 October 1998 (22.10.98) US Not furnished 20 October 1999 (20.10.99) US					
(71) Applicant: FOUNTAINHEAD [US/US]; P.O. Box 5186, Bozeman, MT 59717 (US).		Published <i>With international search report.</i>			
(72) Inventors: KANIA, Bruce; P.O. Box 5186, Bozeman, MT 59717 (US). ZIMMERMAN, David; 10 Pony Street, Pony, MT 59747 (US).					
(74) Agents: McCLELLAND, C., Irvin et al.; Oblon, Spivak, McClelland, Maier & Neustadt, P.C., 4th floor, Crystal Square Five, 1755 Jefferson Davis Highway, Arlington, VA 22202 (US).					
(54) Title: PROSTHETIC DEVICE USING A CAM-SHAPED WHEEL					
(57) Abstract					
<p>A prosthetic device includes an energy storing member (26), a lever member (18) attached to the energy storing member, a rocking member (22), and an energy transfer line (28). This line has a first end (27) attached to a front end (28) of the energy storing member (26) and a second end (29) attached to a back end of the lever member. The line has its middle portion (39) attached to the rocking member (22). The energy storing member (26) is preferably a leaf spring. This combination of elements in the prosthetic device may be a lower leg or foot for use by a below-the-knee amputee to simulate more closely the natural gait of a person while walking or running.</p>					

**BEST AVAILABLE COPY**

*FOR THE PURPOSES OF INFORMATION ONLY*

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	IS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

## TITLE OF THE INVENTION

## PROSTHETIC DEVICE USING A CAM-SHAPED WHEEL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to U.S. Provisional Patent Application Serial No. 60/105,532, filed October 22, 1998, and U.S. Regular Utility Patent Application Serial No. (Attorney Docket No. 9554-0005-3), filed October 20, 1999, from which priority is claimed.

TECHNICAL FIELD

The present invention relates to a prosthetic device for a lower leg or foot for use by a below-the-knee amputee.

BACKGROUND ART

Although prosthetic devices have been in use for centuries, not until relatively recently have efforts been made to design prosthetic legs and feet to react dynamically to the cyclic loading and unloading of the foot during movement to simulate more closely natural gait. To this end, prosthetic devices typically are configured to store and release energy during normal body movements. Typical prosthetic feet include a spring plate arranged longitudinally approximately within the sole of a shoe. The spring plate is usually arranged so as to provide flexure of the foot while walking.

Materials undergo a certain amount of deformation when they are stressed. If a mechanical element experiences a steady deformation when acted upon by steady forces, it is exhibiting compliance which is the basic characteristic of a spring. A translational spring is a mechanical element which deforms by steady amounts when loaded by steady forces. A linear spring has a proportional relation between deformation and force. Thus, the spring stores work as energy associated with its deformation. This stored energy is called translational potential energy. Hence, the energy stored in the spring depends directly on the force transmitted to the spring. In other words, the work done by any force acting on a spring during a specified displacement is equal to the change in the kinetic energy of the spring. This statement is the basic work-energy principle of body dynamics in physics.

The single spring plate of the prior art may have varying thicknesses along its length to give varying compliances across the spring plate in order to simulate more closely the curling movement of a foot during a walking motion. Improvements to the spring plate have included multiple plates of different thicknesses attached or adhered to each other within the prosthetic foot in order to create different compliances along the length of the foot. However, these attempts to achieve different compliances by varying the thicknesses have not been successful because it has been found that spring plates are inherently limited in their simulation of the natural motion of a foot. In particular, as a prosthetic foot using such a spring plate is curled, as it is during a normal walking or running motion, the effort required to curl the prosthetic foot increases, thereby inhibiting the full range of motion. Therefore, it is desirable to provide a prosthetic device that provides a more natural simulation of the motion of a leg or a foot.

#### DISCLOSURE OF INVENTION

Accordingly, it is an object of the present invention to provide a prosthetic device which more naturally simulates the motion of a user's leg or foot.

According to the invention, the prosthetic device is provided with a base portion, a leaf spring attached to the base portion, a lever member hingedly attached to the leaf spring, a rocking member attached to the base portion, and a line having a first end attached to a front end of the leaf spring and having a second end attached to a back end of the lever member. The line has a middle portion, between the first and second ends, that is attached to the rocking member. The prosthetic device can convert a pivoting motion of the lever member into a deflection of the leaf spring, thereby storing energy imparted by the lever member to the leaf spring.

Preferably, the rocking member is an eccentric body, such as a cam-shaped wheel. The line is fixed to the eccentric body such that, as the lever member pivots, the amount of deflection caused in the leaf spring by the pulling of the line changes through the range of foot motion. Accordingly, the eccentric body can be configured such that the deflection of the leaf spring changes over the range of pivoting of the lever member.

### BRIEF DESCRIPTION OF DRAWINGS

A more complete appreciation of the invention and many of the attendant advantageous thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Figure 1 is a side elevational view of a first embodiment of the present invention at the beginning of a step;

Figure 2 is a side elevational view of the embodiment shown in Figure 1 at the midpoint of a step;

Figure 3 is a side elevational view of the embodiment shown in Figure 1 at the completion of a step;

Figure 4 is a side elevational view of a second embodiment of the present invention in a standing position;

Figure 5 is a side elevational view of the embodiment shown in Figure 4 at the beginning of a step;

Figure 6 is a side elevational view of the embodiment shown in Figure 4 at the midpoint of a step;

Figure 7 is a side elevational view of the embodiment shown in Figure 4 at the completion of a step; and

Figure 8 is a top plan view of the embodiment taken through line 8-8 in Figure 4.

### MODES FOR CARRYING OUT THE INVENTION

A prosthetic leg 10 according to the present invention is generally illustrated in Figure 1. It includes a prosthetic sleeve 12 attached to a base portion 14 and configured to be donned over a stump of an amputee. The base portion 14 provides a connection between the prosthetic sleeve 12 and the moving parts of the prosthetic leg 10. The base portion 14 has an extension 15 through which a shaft 23 extends to secure a rocking member 22 thereto. An energy storing member 16 is secured to a bottom 11 of the base portion 14. A flexible lever member 18 is attached to the energy storing member 16 at hinge 20. The energy storing member 16 may be a leaf spring 26 or any other known energy storage means. The leaf spring 26 may be constructed of any known material appropriate for a spring, such as carbon fiber-reinforced plastic, fiberglass, urethane composites and steel. A line 24 may be made

from a strap, cable, cord, rope, or other equivalent element appropriate for transferring energy to and from the leaf spring 26.

Because the lever member 18 is hingedly attached to the leaf spring 26, together they simulate the motion of an ankle. The line 24 has a first end attached to a first point 27 on a front end 28 of the leaf spring 26 while the second end of the line 24 passes through an aperture 25 in the leaf spring 26 and is attached to a second point 29 on a back end 30 of the lever member 18. The line 24 is attached at its midpoint to a tip 39 on the rocking member 22. Note that the distance from the first point 27 to the tip 39 is the same as the distance from the second point 29 to the tip 39. Thus, these two distances are constant and allow the line 24, which is essentially inelastic, to transfer energy back and forth between the lever member 18 and the leaf spring 26. The line 24 is wrapped around the rocking member 22 in a grooved rim such that, as the lever member 18 pivots about hinge 20 in a counterclockwise direction A, the rocking member 22 is also rocked in a counterclockwise direction B, as seen in Figure 2. Since one end of the line 24 is attached to the front end 28 of the leaf spring 26, the pivoting motion of the lever member 18 is converted into a deflection of the leaf spring 26, thereby storing energy in the leaf spring 26.

As shown in Figure 2, at the midportion of a step, the lever member 18 is generally straight, i.e. at a relaxed position. As the user moves through a stepping or walking motion, the lever member 18 is flexed and pivoted relative to the leaf spring 26, similar to the pivoting of a foot about an ankle. During midstep, this pivoting motion allows a lower portion 32 of the lever member 18 to remain substantially in contact with the ground 34 while allowing the prosthetic sleeve 12 and the base portion 14 to follow the motion of the stump of a below-the-knee amputee.

When the user completes a stepping or walking motion, as shown in Figure 3, the energy stored in the leaf spring 26 is returned to the lever member 18. The rocking member 22 may be constructed in the form of either a round wheel or an eccentric body 36, e.g. a cam-shaped wheel with a grooved rim. With the rocking member 22 constructed as the eccentric body 36, it is preferable that the line 24 is fixed at its midpoint to the tip 39 on a lobe 38 of the eccentric body 36. By fixing the line 24 to the tip 39, the eccentric body 36 will be rocked back and forth by the line 24 as the lever member 18 and the leaf spring 26 are flexed and unflexed, respectively.

The amount of force imparted by the lever member 18 to the leaf spring 26 may be modified. For example, it may be preferable to provide more force for a certain user or for users participating in particular activities. Thus, a runner may prefer more force while a walker may prefer less force. Preferably, the line 24 is tensioned between the points 27, 39 and 39, 29 so as to keep the line 24 taut.

A second embodiment of the present invention is shown in Figures 4 through 8. As shown in Figure 4, a prosthetic foot 48 includes a base portion 40 with a heel 41 and an energy storing member which is a leaf spring 42 secured at its back end by a fastener 43 to the heel 41. The base portion 40 has an extension 45 through which the shaft 23 extends to secure the rocking member 22 thereto. A lever member 44 has a front end which serves as a toe portion 47 of the prosthetic foot 48. The lever member 44 is attached to the leaf spring 42 at a hinge 46. The leaf spring 42 is arranged substantially along a direction extending between the heel 41 and the toe portion 47 of the foot 48. The rocking member 22 and the line 24 have the same construction as in the first embodiment.

In this second embodiment, the foot 48 may be provided with a rubber or plastic cover (not shown) which resembles human skin. The operation of the foot 48, according to this second embodiment, is similar to the leg 10 in the first embodiment. For example, as a user moves through a walking motion, the foot 48 moves from the standing orientation shown in Figure 4 sequentially to the step orientations shown at the beginning in Figure 5, at the midpoint in Figure 6, and then at completion in Figure 7. As shown in Figure 5 through 7, and especially in the high stepping position shown in Figure 7, as the lever member 44 pivots in a counterclockwise direction C around the hinge 46, relative to the leaf spring 42, the pivoting movement of the lever member 44 is converted into a deflection of the leaf spring 42. As a user reaches the end of a walking step, the energy stored in the leaf spring 42 is returned through the line 24 to the lever member 44.

As shown in Figure 5, a first end of the line 24 extends from a first point 49 on the front end of the leaf spring 42 to the tip 39 of the lobe 38 on the eccentric body 36. The second end of the line extends from a second point 51 on a back end 50 of the lever member 44, through an aperture 52 in the leaf spring 42 to the tip 39 of the lobe 38 on the eccentric body 36.

Figure 8 shows a top plan view of the leaf spring 42 attached to the lever member 44 by the hinge 46. The leaf spring 42 includes the aperture 52 that is aligned over the second

point 51 on the back end 50 of the lever member 44. This arrangement allows the line 24 to pass through the aperture 52 and to be attached to the second point 51. The leaf spring 42 also has a cutout portion 53 for accommodating the heel 41.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that the invention may be practiced otherwise than as specifically described herein.

CLAIMS:

1. A prosthetic device comprising:  
an energy storing member;  
a lever member attached to the energy storing member;  
a rocking member; and  
an energy transfer line having a first end attached to the energy storing member and having a second end attached to the lever member, said energy transfer line having a middle portion attached to the rocking member.
2. A prosthetic device according to Claim 1, wherein the lever member is attached to the energy storing member at a hinge.
3. A prosthetic device according to Claim 1, wherein the prosthetic device is a leg and wherein the lever member is positioned for contacting ground.
4. A prosthetic device according to Claim 1, wherein the rocking member is a cam-shaped wheel with a grooved rim.
5. A prosthetic device according to Claim 1, wherein the middle portion of the energy transfer line is attached to a tip of a lobe on the rocking member.
6. A prosthetic device according to Claim 1, further comprising a base portion and a sleeve being attached to the base portion and also being configured to be donned over a stump of an amputee.
7. A prosthetic device according to Claim 6, wherein the energy storing member and the rocking member are both attached to the base portion.
8. A prosthetic device according to Claim 1, wherein the lever member has a front end and a back end and the energy storing member is a leaf spring having a front end and a back end.
9. A prosthetic device according to Claim 8, wherein the lever member is hingedly attached to the front end of the leaf spring.
10. A prosthetic device according to Claim 8, wherein the leaf spring has an aperture through which the energy transfer line passes.

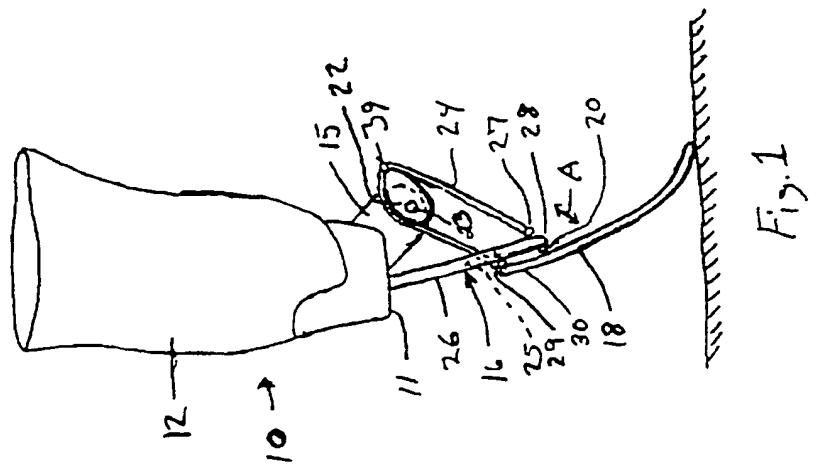
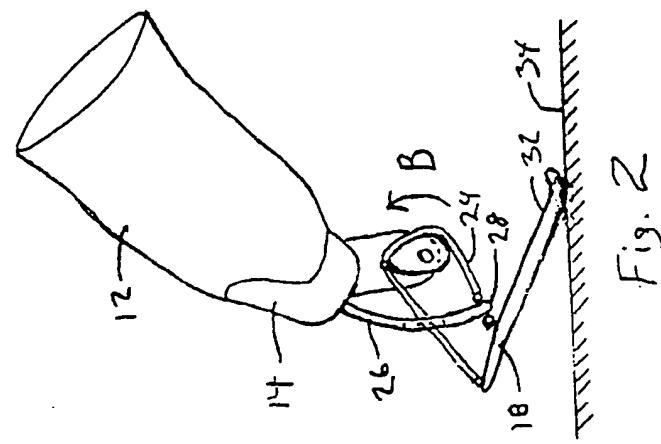
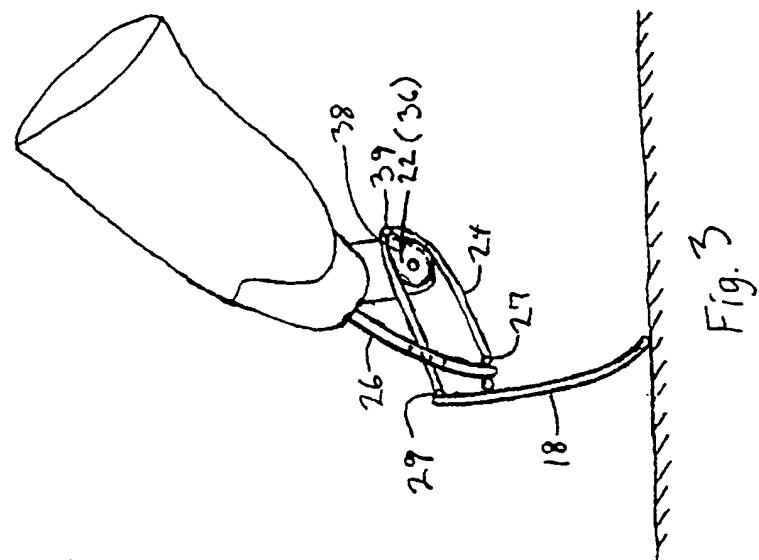
11. A prosthetic device according to Claim 8, wherein the first end of the energy transfer line is attached to the front end of the energy storing member and the second end of the energy transfer line is attached to the back end of the lever member.

12. A prosthetic device according to Claim 8, wherein the prosthetic device is a prosthetic foot and wherein the leaf spring is arranged substantially along a direction extending between a heel portion and a toe portion of the prosthetic foot.

13. A prosthetic device according to Claim 12, wherein the back end of the leaf spring is fastened to the heel portion of the prosthetic foot.

14. A prosthetic device comprising an energy storing member, a lever member attached to the energy storing member, and a rocking member connected between the energy storing member and the lever member, wherein potential energy stored in the energy storing member is transferred to the lever member via the rocking member.

15. A prosthetic device according to Claim 14, wherein the rocking member is a cam-shaped wheel.



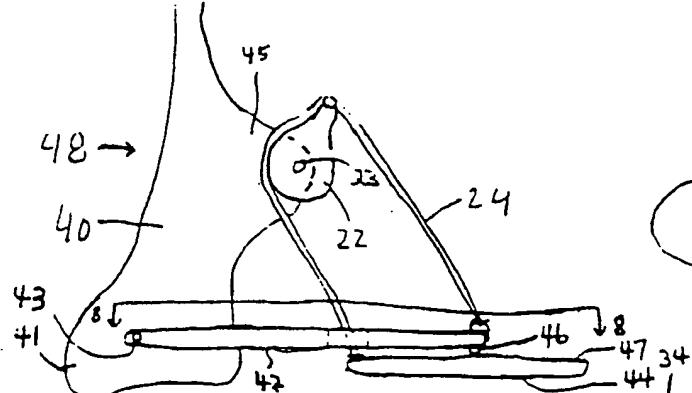


FIG. 4

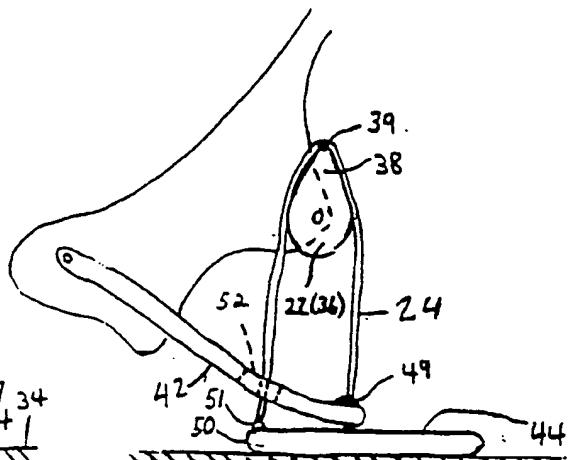


FIG. 5

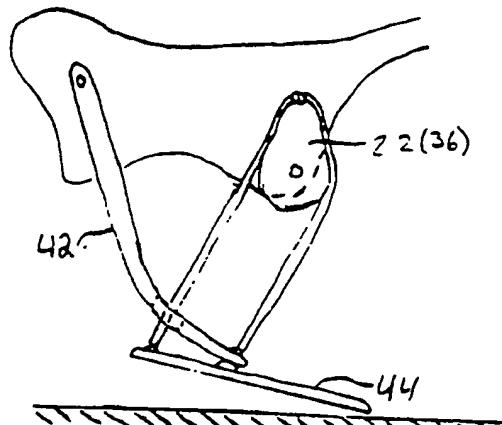


FIG. 6

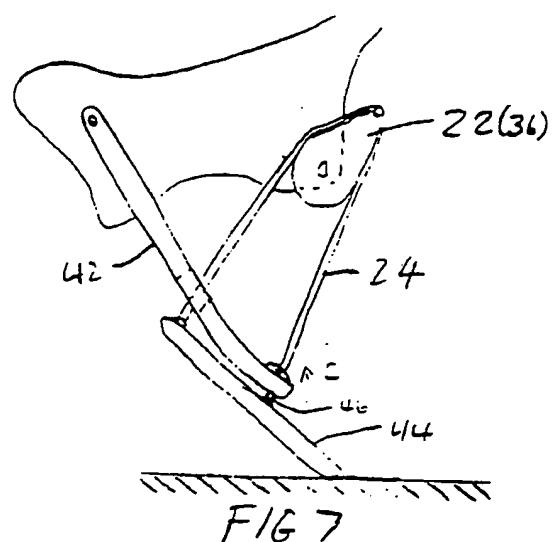


FIG. 7

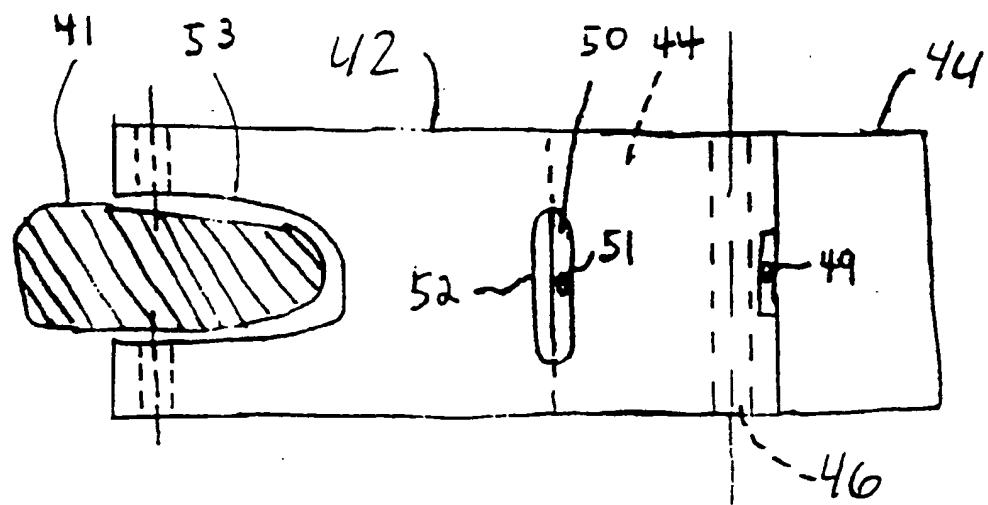


FIG. 8

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US99/23971

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) : A61F 02/66, 74  
US CL. : 623/27, 52

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 623/52, 27

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST, WEST

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,941,913 A (WOOLNOUGH et al), Figs. 1-5. <i>24 August 1999</i>	1, 14
A	US 5,800,568 A (ATKINSON et al.) 01 September 1998, Figs. 5A and 5B.	1, 14
A	US 1,023,247 A (FREES) 16 April 1912, entire document.	1, 14
A	US 5,376,141 A (PHILLIPS) 27 December 1994, Figs. 7-9.	1, 14

Further documents are listed in the continuation of Box C.

See patent family annex.

• Special categories of cited documents:	
"A"	document defining the general state of the art which is not considered to be of particular relevance
"E"	earlier document published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"Z"	document member of the same patent family

Date of the actual completion of the international search

27 DECEMBER 1999

Date of mailing of the international search report

21 JAN 2000

Name and mailing address of the ISA/US  
Commissioner of Patents and Trademarks  
Box PCT  
Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

ALVIN STEWART

Telephone No. (703) 305-0277

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

CORRECTED VERSION

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
27 April 2000 (27.04.2000)

PCT

(10) International Publication Number  
**WO 00/23017 A1**

(51) International Patent Classification: **A61F 2/66. 2/74**

(72) Inventors: KANIA, Bruce: P.O. Box 5186, Bozeman, MT 59717 (US). ZIMMERMAN, David: 10 Pony Street, Pony, MT 59747 (US).

(21) International Application Number: **PCT/US99/23971**

(74) Agents: McCLELLAND, C., Irvin et al.: Oblon, Spivak, McClelland, Maier & Neustadt, P.C., 4th floor, Crystal Square Five, 1755 Jefferson Davis Highway, Arlington, VA 22202 (US).

(22) International Filing Date: 21 October 1999 (21.10.1999)



(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

(48) Date of publication of this corrected version:

8 March 2001

(15) Information about Correction:

see PCT Gazette No. 10/2001 of 8 March 2001, Section II

**Published:**

— *With international search report.*

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

**BLACK BORDERS**

**IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**

**FADED TEXT OR DRAWING**

**BLURRED OR ILLEGIBLE TEXT OR DRAWING**

**SKEWED/SLANTED IMAGES**

**COLOR OR BLACK AND WHITE PHOTOGRAPHS**

**GRAY SCALE DOCUMENTS**

**LINES OR MARKS ON ORIGINAL DOCUMENT**

**REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**

**OTHER:** \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**